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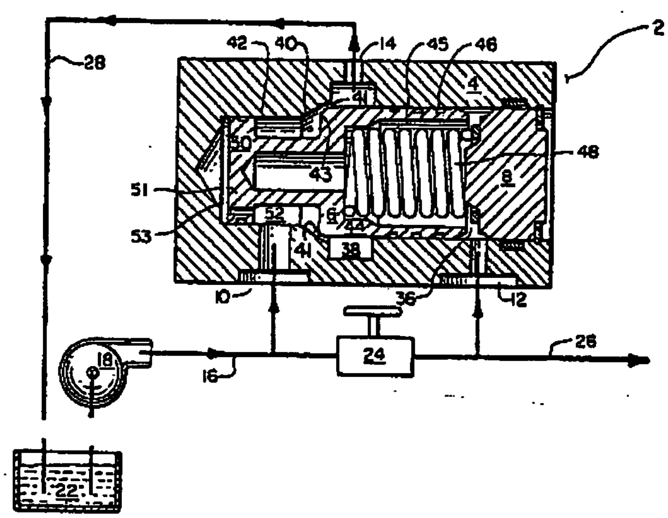
(54) Title: LIQUID FLOW CONTROLLER HAVING PRESSURE BALANCED PISTON FOR DELIVERING CONSTANT FLOW



(57) Abstract

A small, lightweight, simple, and highly reliable flow controller (2) utilizing two moving parts (6, 48), for apportioning inlet fluid flow between an orifice outlet (26, 16) and inlet. Constant outlet flow over a substantial inlet flow and pressure range is achieved through the use of a flow balanced flow control piston (6) reciprocating internally of a housing (4). The balanced piston is biased to a predetermined proportioning range through an internal spring (48). The unit is normally operated with inlet port and outlet pressure sensing port in fluid communication with an external orifice (24). A bypass port (14) communicating with the controller inlet adjacent the control piston returns excess fluid to the reservoir (22) of a pumped fluid system. Increases in inlet flow to the regulator/orifice combination act to adjust the balanced piston position and initiate or increase flow across an integral piston/seat control orifice. The downstream or outlet pressure of the external orifice is sensed by an equal piston area distal the cylinder seat and/or inlet side of the piston. A damping piston (50) abuts said inlet pressure sensing portion of the piston in order to minimize transient piston motion or chatter.

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LIQUID FLOW CONTROLLER HAVING PRESSURE BALANCED PISTON FOR DELIVERING CONSTANT FLOW

SPECIFICATION

BACKGROUND OF THE INVENTION

This invention relates generally to proportional constant delivery fluid flow controllers, and more particularly to the type of controller wherein the pressures of the fluid supply and delivered fluid are applied to the opposite ends of a reciprocating piston in order to maintain constant volume flow to a load.

Many proportional controllers are in use, however, in most cases, this type of controller utilizes an isolated pressure sensing element which is mechanically or electrically linked to a flow controller which acts to apportion inlet flow in accordance with predetermined flow and/or pressure ranges. In most cases, this type of controller is a force-balance device wherein the restoring or predetermined flow range is provided through a mechanical spring acting on the pressure sensing surface. These controllers, although highly satisfactory and reliable, employ separate pressure sensing and flow controlling means. Therefore, the complete device is generally complicated, and expensive. Further, due to the physical separation of the pressure sensing and flow controlling elements, it is difficult to flow- and pressure-balance the apportioning flow control member.

It is well known in the control art that proportional regulators inherently require an error in order to invoke a compensating action. Thus, these units are commonly termed "droop" controllers, indicating that for a given sensitivity to inlet and outlet pressure, the compensating or corrected flow must vary over the extremes of the control range or proportional band. It is further

well known in the control art that minimizing the droop is achieved by increasing the controller sensitivity or gain. However, high gain proportional controllers are generally unstable, and require additional stabilizing elements in order to achieve desired output control over a predetermined inlet variation, further increasing cost of the typical conventional controller.

BRIEF DESCRIPTION OF THE INVENTION

The device disclosed here is novel in that proportionality is achieved through pressure balancing a single reciprocating piston through the use of essentially equal pressure sensing areas on either end of the piston or closure member. With the units' inlet and outlet portions in fluid communication, i.e. connected across a flow control orifice, both delivered or outlet fluid pressure and inlet fluid pressure act on the common piston, thereby translating the piston in accordance with the pressure drop occasioned by variations in supply pressure and/or demand. The inlet portion of the control piston and its' surrounding housing define a variable control orifice and bypass port. Therefore, in operation, for each combination of orifice outlet and inlet pressure, the piston assumes a location internal the housing and a corresponding bypass flow. Due to the piston/seat design however, piston forces remain essentially balanced, resulting in very small proportional error.

As disclosed, the proportional bypass flow controller is extremely simple in operation, employing two moving parts. The novel pressure balanced piston allows the use of a relatively high rate balancing spring providing an effective high proportional gain.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional view of the regulator disclosed, particularly showing the reciprocating integral piston and poppet assembly, with input, output, and bypass ports, all in the closed or non-bypassing condition.

Figure 2 is an additional cross-sectional view of Figure 1 incorporated into a semi-schematic diagram of the regulator of the invention in a preferred hydraulic circuit, particularly showing an associated flow orifice.

Figure 3 is a diagram of the system particularly showing the functional equivalents of the regulator of the invention, and preferred system.

DETAILED DESCRIPTION OF THE INVENTION

With principal reference to Figure 1, the controller of the invention utilizes a piston/damping assembly 6, mounted for reciprocal motion internal of the controller housing or body 4. The piston assembly comprises a poppet closure portion 43 cooperating with an internal connoidal poppet seat 40. The poppet closure 43 is intermediate a damping piston portion 50, and a piston barrel portion 44 of the piston assembly 6. The barrel portion of the piston assembly defines a piston cavity 45 containing the controller proportioning spring 48. Adjacent the open end of the cavity 45 is a plug and spring retainer 8, having an internal surface abutting the controller proportioning spring for establishing initial closure force for biasing or calibrating the poppet closure portion 43 of the piston assembly 6 against the cavity seat 40. The controller body cavity 36 and the piston barrel cavity 45 are in fluid communication with the outlet fluid pressure exiting the orifice 24 via outlet port 12.

Bypass fluid flow enters the circumferential bypass flow volume 52 via the inlet orifice 10. Bypass flow passing through the variable poppet control orifice 41 enters the circumferential bypass flow volume 38 and exits the flow controller through the bypass outlet port 14 for return to the sump 22 via conduit 28.

With reference to Figure 2, and occasional mention of Figure 1, the controller 2 of the invention is shown having a fluid supply delivered by a pump 18 through a conduit 16 to the controller inlet port 10. Fluid supplied by conduit 16 also passes through external orifice 24. The fluid pressure at the outlet of orifice 24 is applied to the controller via outlet orifice 12. The pressure of fluid exiting orifice 24 is sensed at 12, fluid is then transmitted to an external system (not shown) via conduit 26.

Bypass fluid flow entering the inlet orifice 10 passes through flow volume 52 and a variable orifice 41 defined by the regulator cavity seat 40 and the poppet closure portion 43 of the fluid control piston assembly 6. The bypass fluid then enters the controller body cavity circumferential bypass flow area 38. Cavity 38 is in fluid communication with the controller bypass outlet port 14 and is returned to the fluid sump 22 through bypass flow conduit 28.

The flow control piston barrel 44, incorporates a plurality of grooves 46 at its outer periphery. As the piston/cylinder diametral clearance is relatively small, these grooves act as a labyrinth seal between the cooperating surfaces of piston barrel and cylinder inner wall. The low friction characteristic of this type of fluid seal greatly reduces the force hysteresis or "stiction" opposing movement of the piston pressure sensing assembly

6 within the flow control body cavity or cylinder 36. This structure greatly increases the sensitivity of the disclosed controller to small variations in differential or flow pressure across the effective piston areas at or adjacent to the poppet closure member at 43, and the flow control barrel 45.

In operation, with the proportioning spring adjusted for a predetermined force or calibrated flow, pumped fluid entering the inlet port 10 and passing through the flow orifice 24 for delivery to the outlet conduit 26, establishes a pressure drop across the orifice 24. The upstream pressure is exerted within the bypass cavity 52, and acting on the effective area of the piston poppet portion of the piston assembly 6, forces the piston assembly in a direction opposing the biasing force of the spring 48.

When the piston upstream pressure exceeds a predetermined value, overcoming the spring biasing force, movement of the piston disengages the poppet closure portion 43 from its cooperating seat 40 allowing bypass flow to enter the cavity 38 through variable flow control orifice 41. Variations in pumped supply volume and pressure are therefore controlled through the piston motion, thereby bypassing varying quantities of fluid in order to maintain a constant output or flow volume to the conduit 26. In the event that the outlet pressure sensed via outlet port 12 were to decrease, the motion of the piston assembly would further increase fluid bypass, thereby maintaining the constant volume flow. Conversely, should the outlet pressure increase, piston movement would decrease the amount of bypass fluid, thereby maintaining the outlet volume flow.

As those skilled in the control art will readily comprehend, action of the biased piston assembly 6 acts as a proportional controller in that, fluid is bypassed in proportion to the pressure drop exerted on either end of the piston assembly, thus maintaining constant fluid output. Further, the controller disclosed, due to the novel design of the poppet closure portion 43 as it cooperates with the body cavity seat 40, establishes a pressure balanced operating environment for the piston assembly 6.

The balanced nature of the piston is due to essentially equal diameters of the effective pressure sensing area at the poppet control orifice 41, and the effective pressure sensing areas of the piston barrel 44 adjacent the body cavity 36. Additionally, due to the large change in flow area of poppet control orifice 41 with small axial movements of piston 6, the proportional gain or proportionality constant between pressure differential across the piston and bypassed fluid is high, resulting in a low droop or low proportional error controller. As indicated on the attached Table I, delivered fluid flow is controlled to close tolerances.

The piston assembly of the controller of this invention also incorporates a damping portion consisting of an integral damping piston 50, reciprocating in a reduced diameter portion 42 of the body 4. The damping piston head 51, also incorporates a damping orifice 53. In operation, as the bypass cavity 52 is completely filled with the controlled fluid, movement of the piston assembly 6 carries the volume of the reduced diameter portion of the cavity adjacent the damping piston head, thus forcing fluid through the orifice and into or out of the damping volume 54. Thus, the incorporation of a damping means insures that operation of the disclosed

controller minimizes the possibility of pressure or fluid flow transients in the delivered fluid at the outlet of the controller.

Those skilled in the regulator and control arts will readily comprehend that inclusion of damping allows utilization of much higher proportional gain as demonstrated in the controller disclosed herein.

The schematic system diagram of Figure 3 discloses the functional aspect of the controller of the invention as used in a typical but not limiting application, wherein fluid is supplied through outlet conduit 26 to a system load 27, exhibiting a variable resistance to outlet fluid flow therethrough. As shown, in order to aid in disclosure, outlet of 27 is shown returned to the fluid sump 22. Those skilled in the art will readily recognize that this system is "typical" and that other types of varying demand would demonstrate the control function as well.

In operation, supply pump 18 deliveries fluid via 16 to the schematically depicted regulator 2 via conduit 14. Fluid through conduit 16 is also supplied through variable orifice 24, to the outlet conduit 26. Outlet pressure of conduit 26 is supplied to the fluid control valve 2 via conduit 12. Elements of the analogous controller 2 corresponding to those in the flow controller of the invention are indicated as identical numbers carrying the prescript prime. Therefore, inlet pressure from conduit 12 acts on system barrel 44 prime, as does the inlet pressure at conduit 16 acts on effective pressure sensing area 43 prime of the piston poppet assembly 6. Equivalent flow control seat 40 prime cooperates with piston control portion 43 prime to deliver a pressure sensitive bypass fluid flow via outlet port 10 prime, returning to the equivalent sump 22 prime.

As those skilled in the control arts will readily see, the controller of the invention incorporates features of a novel structure, incorporating all of the features of more expensive and complicated controllers, with a unit having two moving parts.

Thus, it is apparent that there has been provided in accordance with the disclosed invention a proportional fluid flow controller that is small, light in weight, and employs two moving parts. While the controller as disclosed has been described in two preferred embodiments, it is evident that those skilled in the art will be aware of many evident alternatives, modifications, and variations. Accordingly, the invention as disclosed contemplates and embraces all such alternatives, modifications and variations as may fall within the spirit and broad scope of the appended claims.

Therefore, I claim:

TABLE I

Inlet Flow Calb.	P, Notes	Delta P.	Bypass Port Press.	Bypass Flow	Outlet Flow,
.78 GPM				.29 GPM	.29 GPM
Restrictor					
300 PPH	10 psi	10 psi	0 psi	112 PPH	189 PPH
Valve Set					
1.04 GPM				.50 GPM	.54 GPM
400 PPH	10 psi	10 psi	.3 psi	192 PPH	208 PPH
Restrictor					
1.30 GPM				.80 GPM	.50 GPM
Valve Set					
500 PPH	10 psi	10 psi	.9 psi	308 PPH	192 PPH

1. In a proportional controller for delivering constant fluid volume flow at an outlet over a range of varying pumped fluid input pressures and/or outlet demand, of the type incorporating pressure controlled variable bypass flow, the improvement comprising;

a generally cylindrical housing;

a reciprocating pressure balanced flow control piston further in said housing comprising;

a first end incorporating a damping head;

a second end opposite said first end;

a reduced diameter portion abutting said damping head and cooperating with said housing to define a flow volume;

a first pressure sensing area adjacent said reduced diameter portion;

a second pressure sensing area essentially equal to said first pressure sensing area defined by said second end;

a poppet flow control shoulder intermediate said first and second pressure sensing areas;

wherein fluid inlet pressure exerted on said first sensing area and outlet pressure exerted on said second pressure sensing area, act to apportion bypass flow through said reduced diameter portion.

2) The piston defined in claim one further comprising;

an increased diameter portion intermediate said flow control shoulder and second end;

a slot in said housing radially adjacent said increased diameter portion, thereby defining a circumferential flow area.

3) In combination;.

a fixed flow control orifice, having an inlet and outlet;

a proportional controller having a fluid inlet, bypass outlet, and a pressure sensing port;

said controller comprising;

a generally cylindrical housing; and,

a reciprocating, pressure balanced flow control piston in said housing further comprising;

a first end incorporating a damping head;

a second end on said piston opposite said first end;

a reduced diameter portion abutting said damping head and cooperating with said housing to define a flow volume;

a first pressure sensing area adjacent said reduced diameter portion;

a second pressure sensing area essentially equal to said first pressure sensing area, defined by said second end;

a poppet flow control shoulder intermediate said first and second pressure sensing areas;

means communicating said flow volume and controller bypass outlet;

means communicating said flow control orifice inlet, controller inlet, and first pressure sensing area;

means communicating said flow control orifice outlet, controller sensing port, and second pressure sensing area;

wherein variable fluid inlet pressure, and outlet flow demand coact with said regulator first and second pressure sensing areas respectively to position said flow control piston and maintain the predetermined outlet flow.

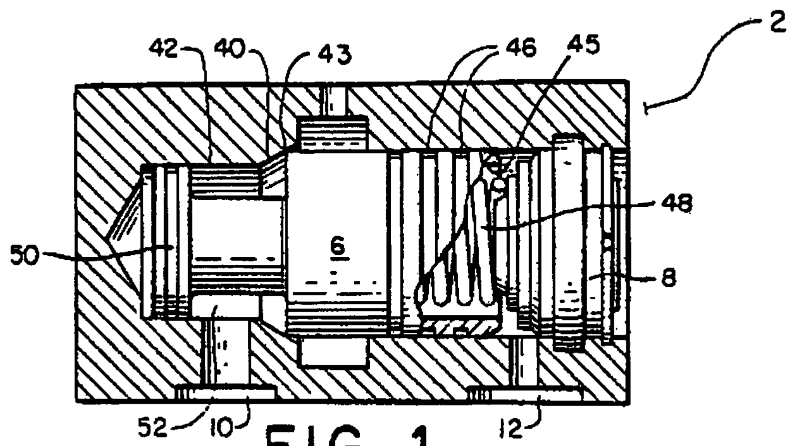

FIG. 1

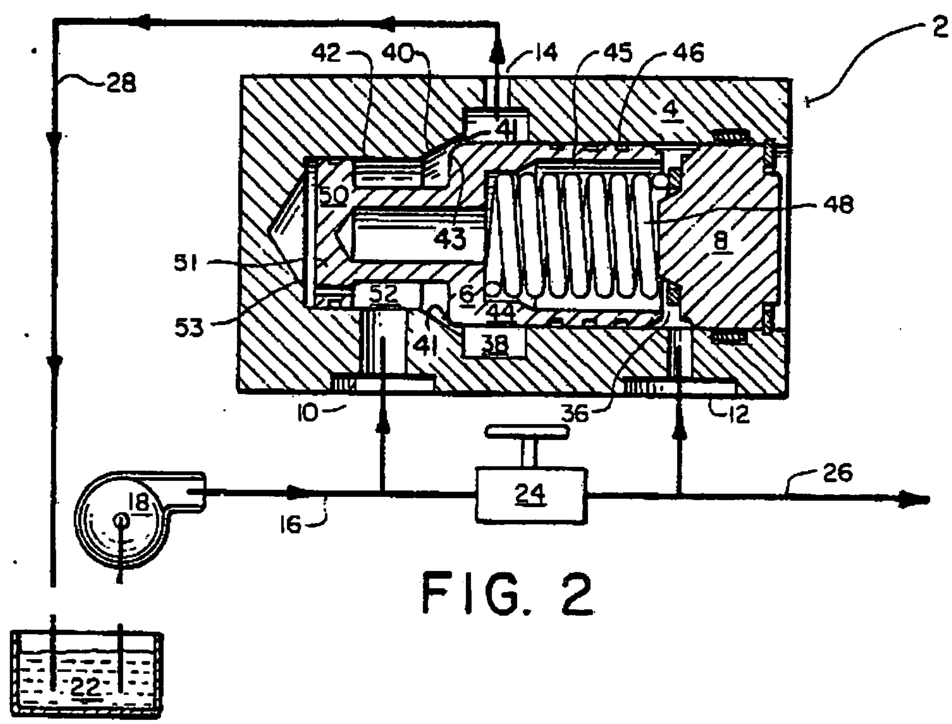

FIG. 2

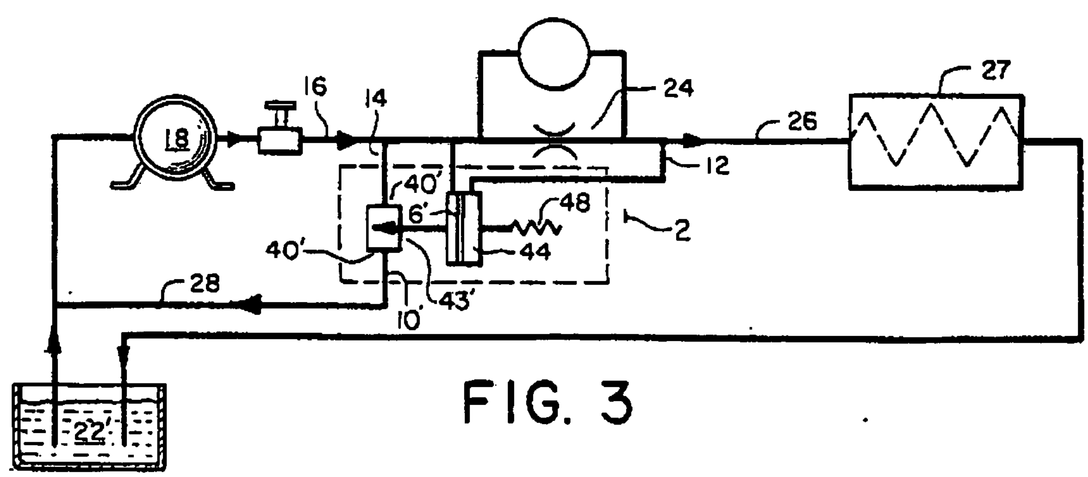

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No PCT/US85/01070

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.[3] G05D 7/01, G05D 11/03
U.S. CL. 137/117

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	137/117

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A, 3,411,416, Herd 19 November 1968	1-3
Y	US, A, 2,748,947, Jay 05 June 1956	1-3
Y	US, A, 1,804,751, Doble 12 May 1931	1-3

* Special categories of cited documents: [15]
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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [3]
11 July 1985	30 JUL 1985
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	ALAN COHAN